Integration of operational aspects of power plants in planning models

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Context

- Low-carbon energy system:
  - Large contribution of RES predicted, especially in the electricity sector
- Increasing share intermittent RES:
  - Variability supply > variability demand => increased need of flexibility (of conventional power plants)
  - Wind, PV: Seasonal and diurnal patterns + large deviations ⇔ Electricity demand

Research Question

- What is the impact of:
  - A) TS Division/Temporal resolution
  - B) Limited technical detail

  on the quality of the outcome of planning models?

Model Description

- Methodological analysis with a small TIMES model based on the Belgian electricity system
  - Single Region, No Import/export (Island operation)
  - No grid
  - Limited set of technologies
  - Base year + 4*10-year period
  - RES targets imposed (50% in 2050)
  - 5% Capacity margin (peaking equation)
  - Linearly increasing CO_2-tax

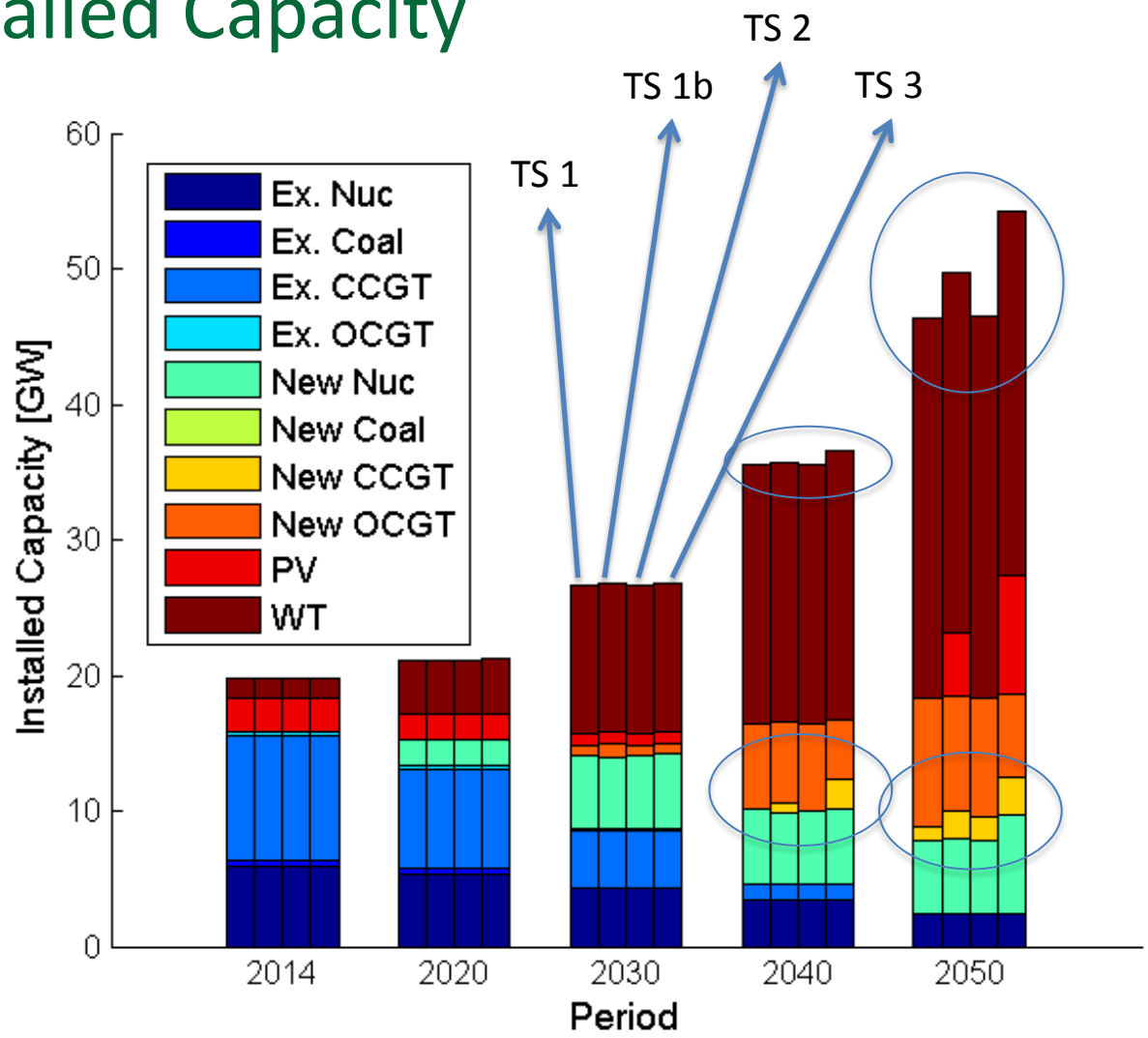
Model Description

- 4 TS divisions considered:

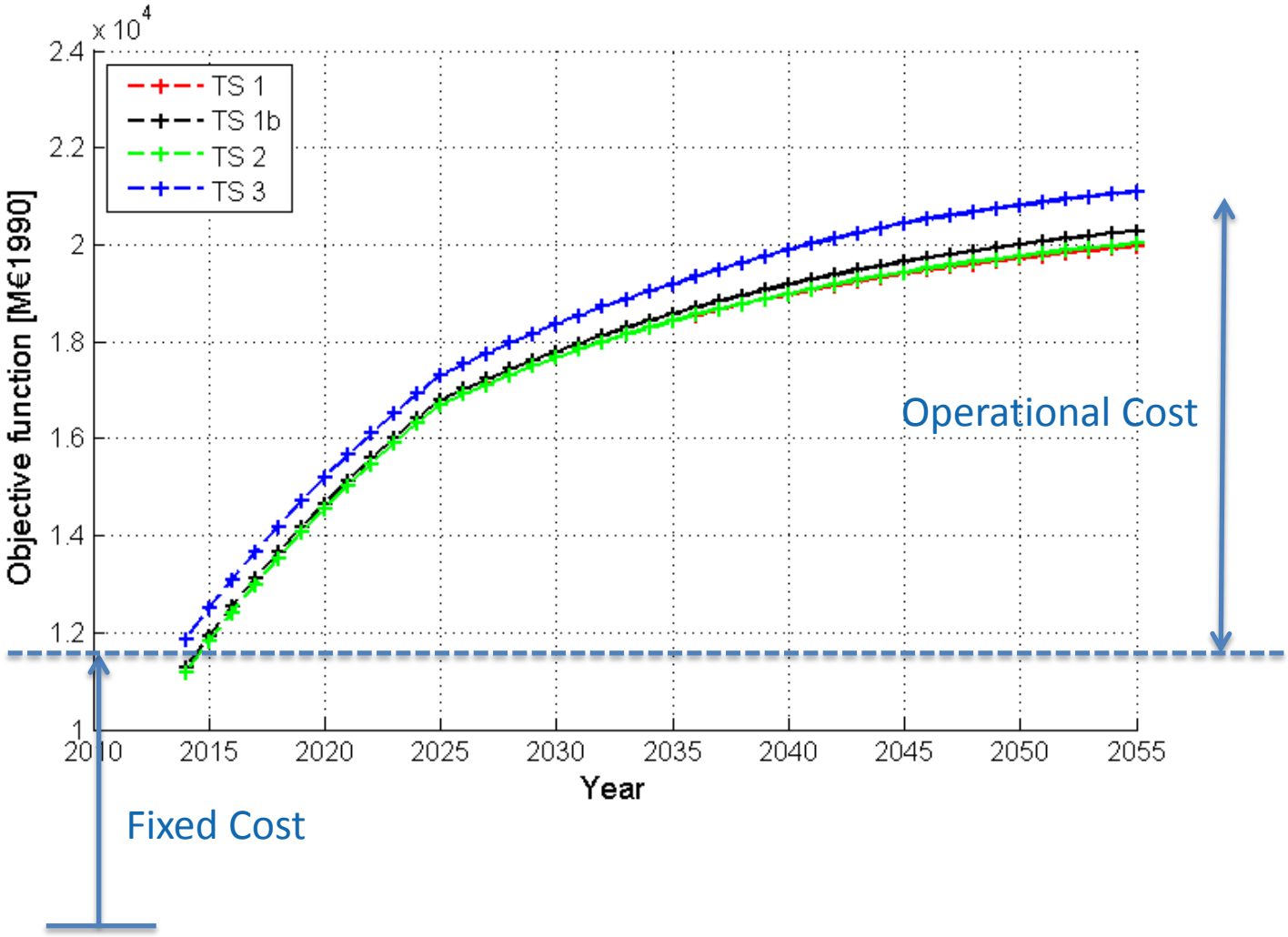
	TS 1	TS 1b	TS 2	TS 3
SEASON	4 Seasons	4 Seasons	4 Seasons	52 weeks
WEEKLY		Day, Night, Peak	WD, Sat, Sun	7 days/week
DAYNITE	Day, Night, Peak	High Wind, Med Wind, Low Wind	24 h/day	24h/day
# TS	12	36	288	8736

Model Results - Capacity

- Installed Capacity



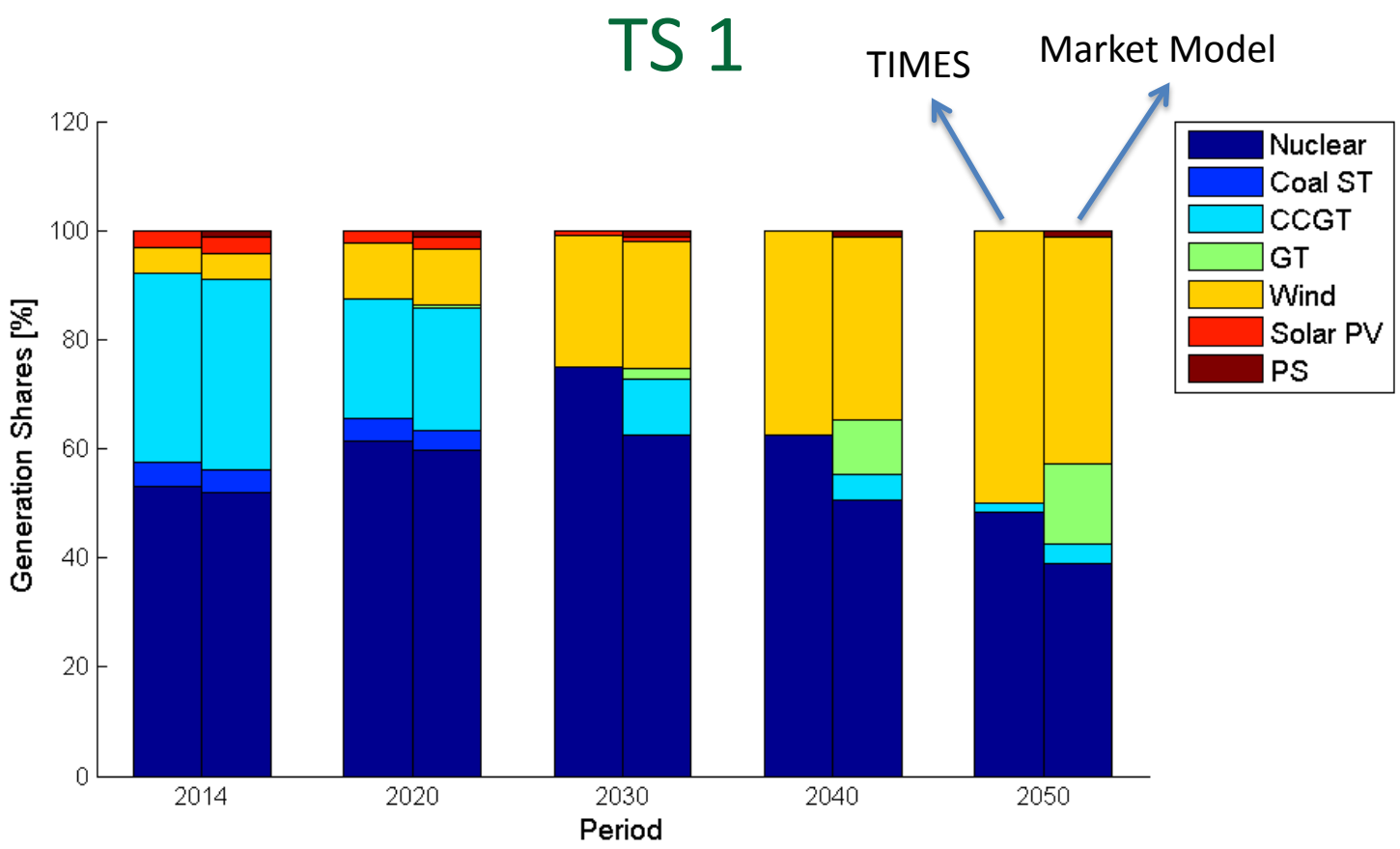
Model Results – System Cost



Re-evaluate Dispatch

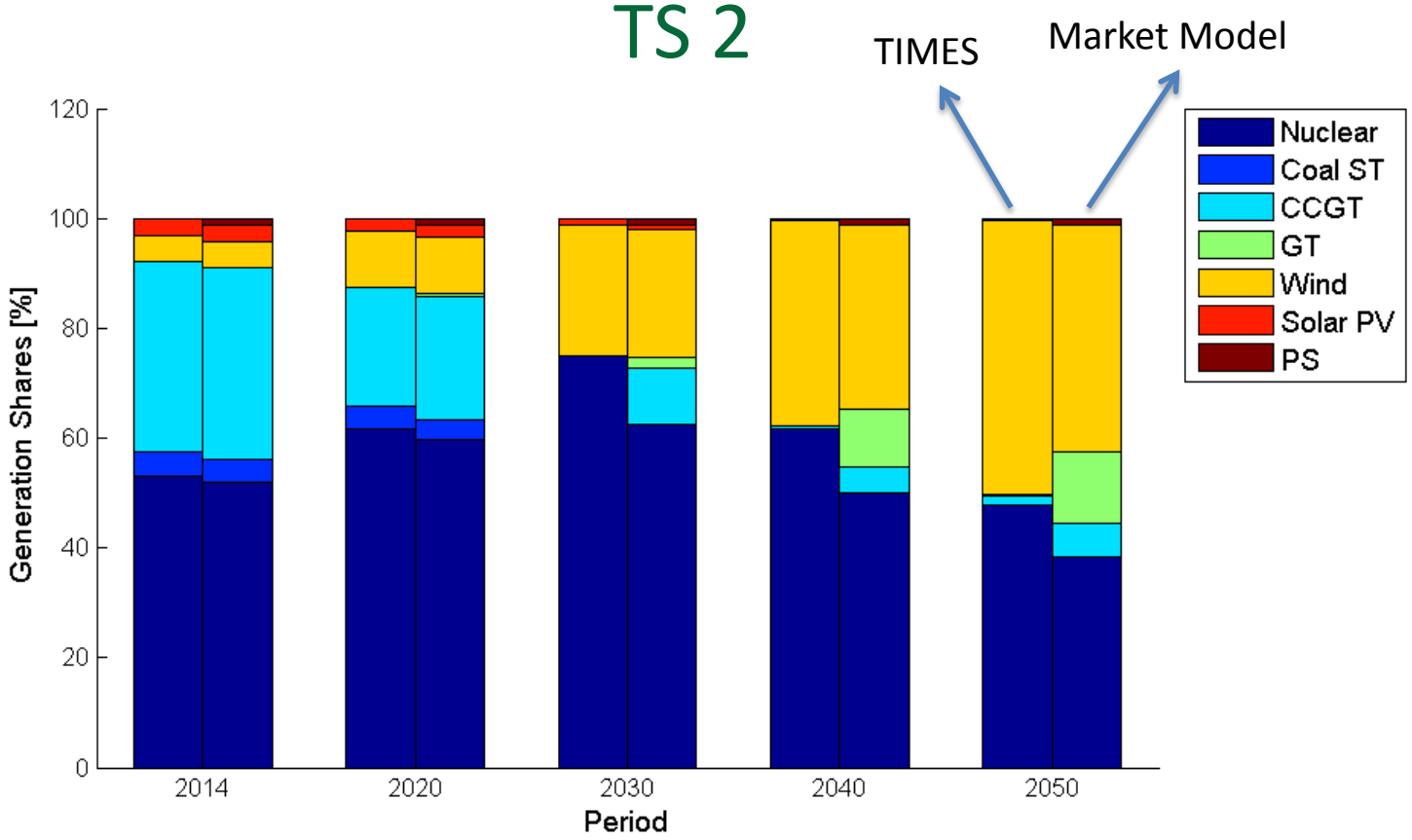
- Re-evaluate dispatch decisions
- MILP market model:
  - Capacity variables TIMES = input data
  - Market model:
    - Hourly resolution (8736 periods)
    - dispatch at power plant level, includes operational constraints (ramping rates, minimal generation level, minimal up and down time, etc.)
    - No operational reserves, no grids

Re-evaluate Dispatch – TS 1



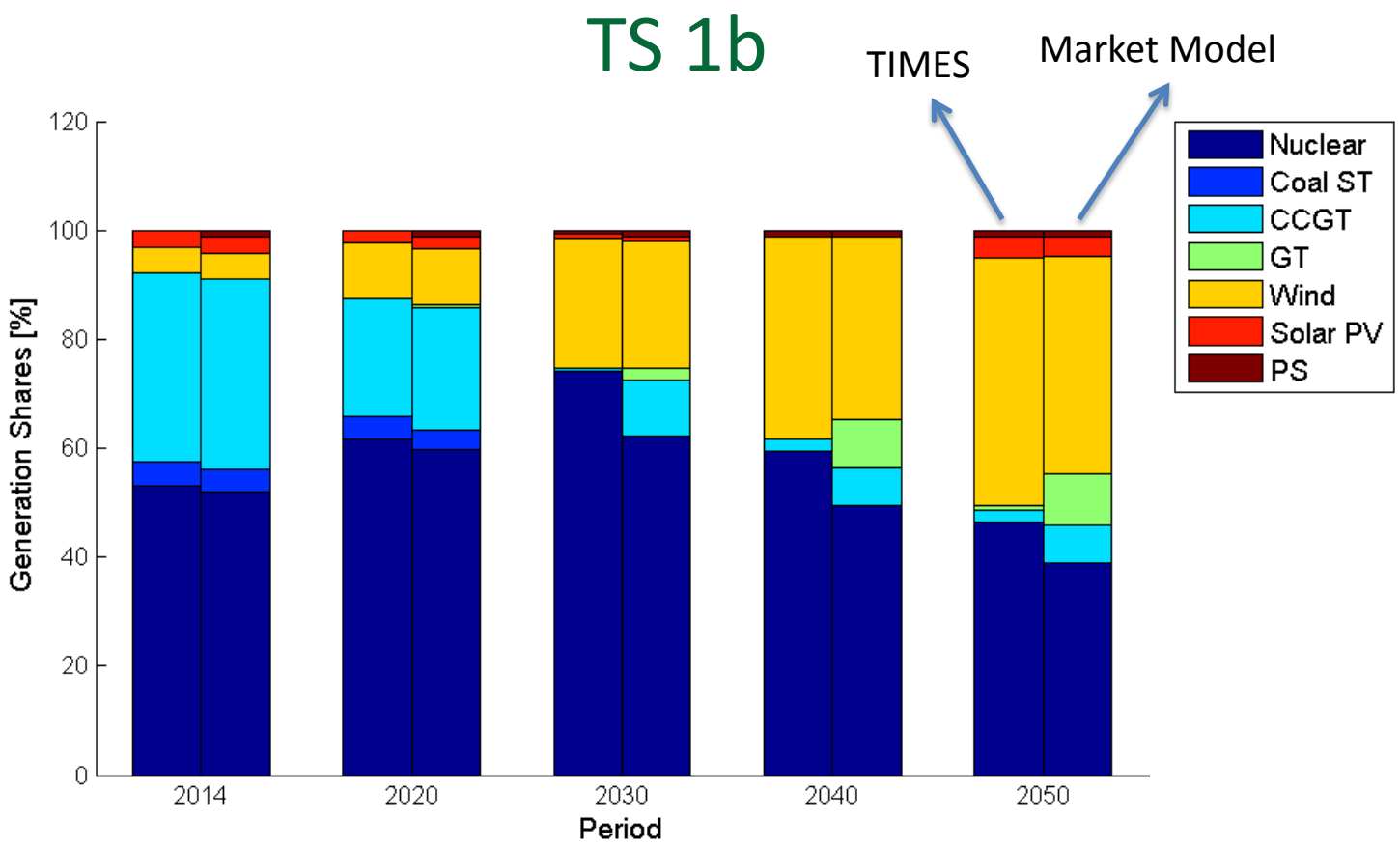
RES Target [%]:	/	12.5	25	37.5	50
Share RES [%]:	7.6	12.3	24.0	33.5	41.5

Re-evaluate Dispatch – TS 2



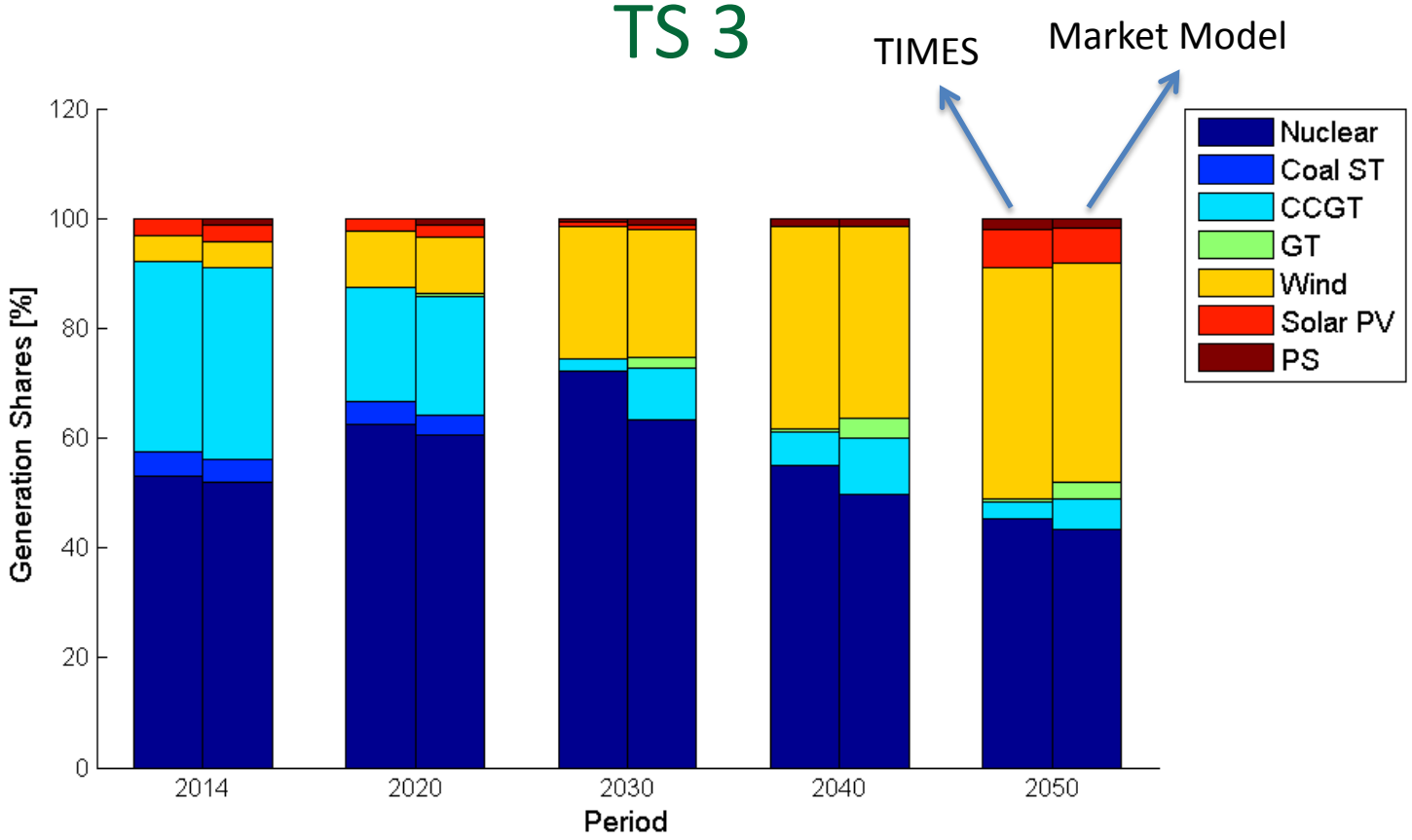
RES Target [%]:	/	12.5	25	37.5	50
Share RES [%]:	7.6	12.3	24.0	33.5	41.5

Re-evaluate Dispatch – TS 1b



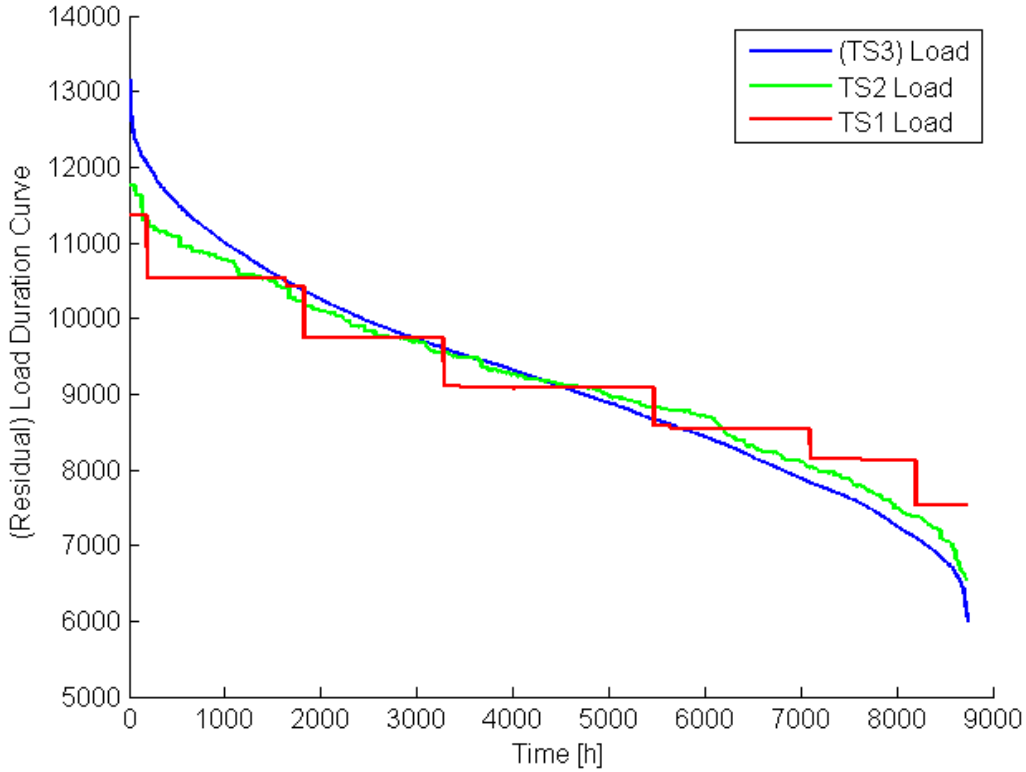
RES Target [%]:	/	12.5	25	37.5	50
Share RES [%]:	7.6	12.3	24.0	33.6	43.4

Re-evaluate Dispatch – TS 3



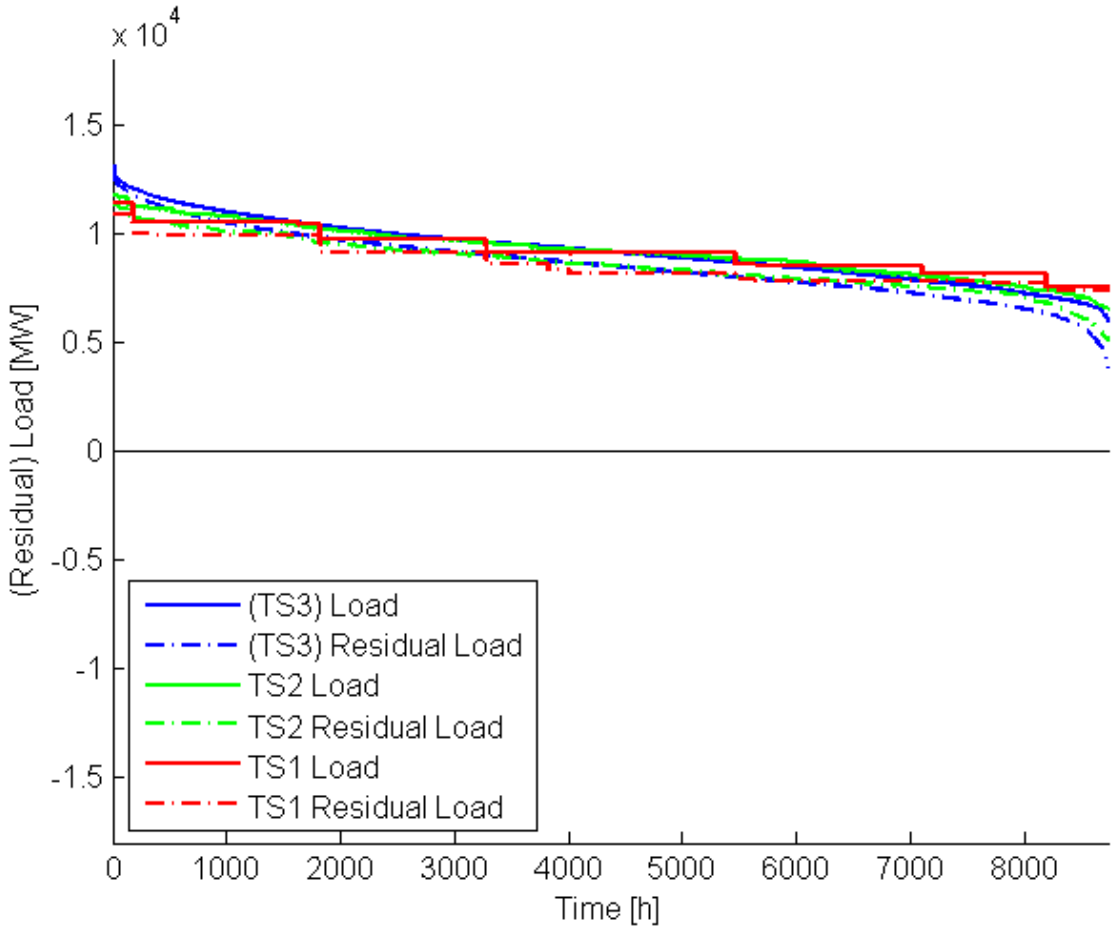
RES Target [%]:	/	12.5	25	37.5	50
Share RES [%]:	7.6	12.3	24.0	34.9	46.5

Residual Load Duration Curve (RLDC)



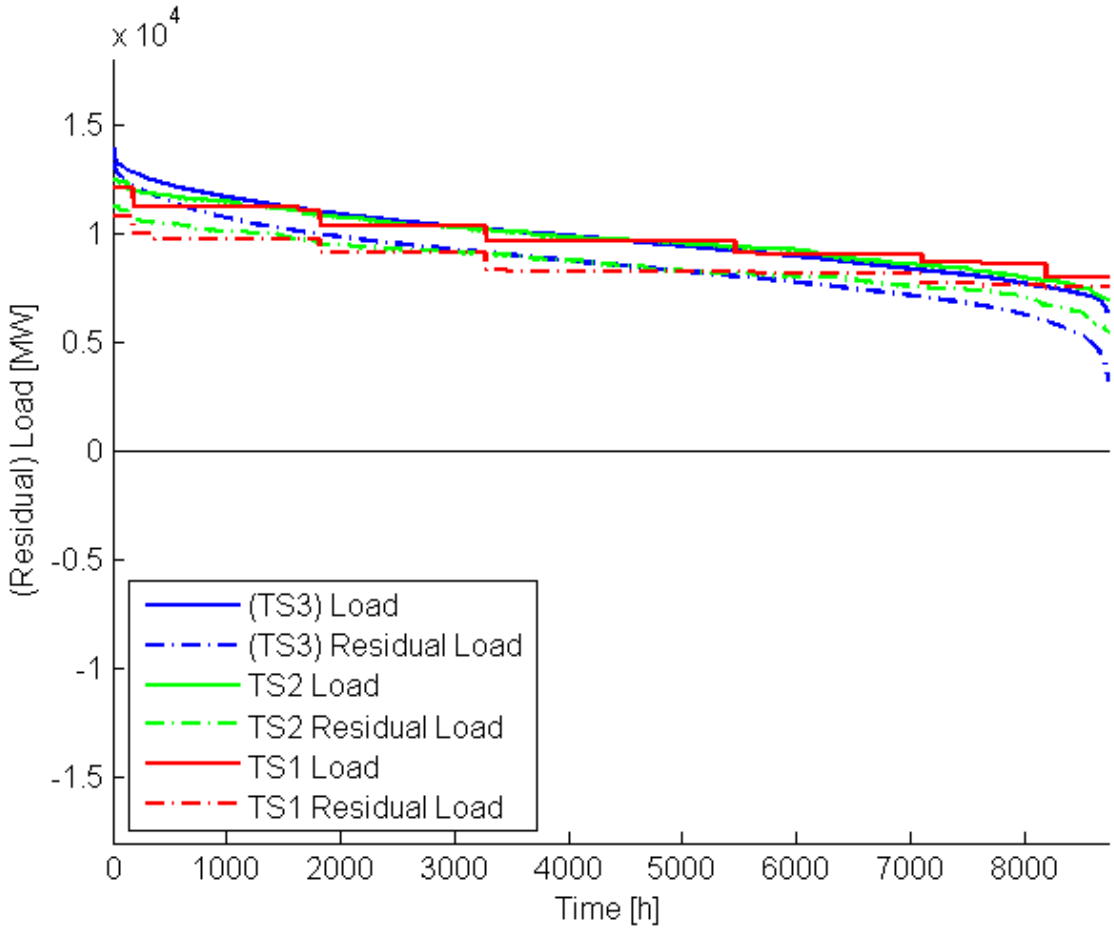
Residual Load Duration Curve (RLDC)

- 2014: 1.5 GW Wind, 2.5 GW PV



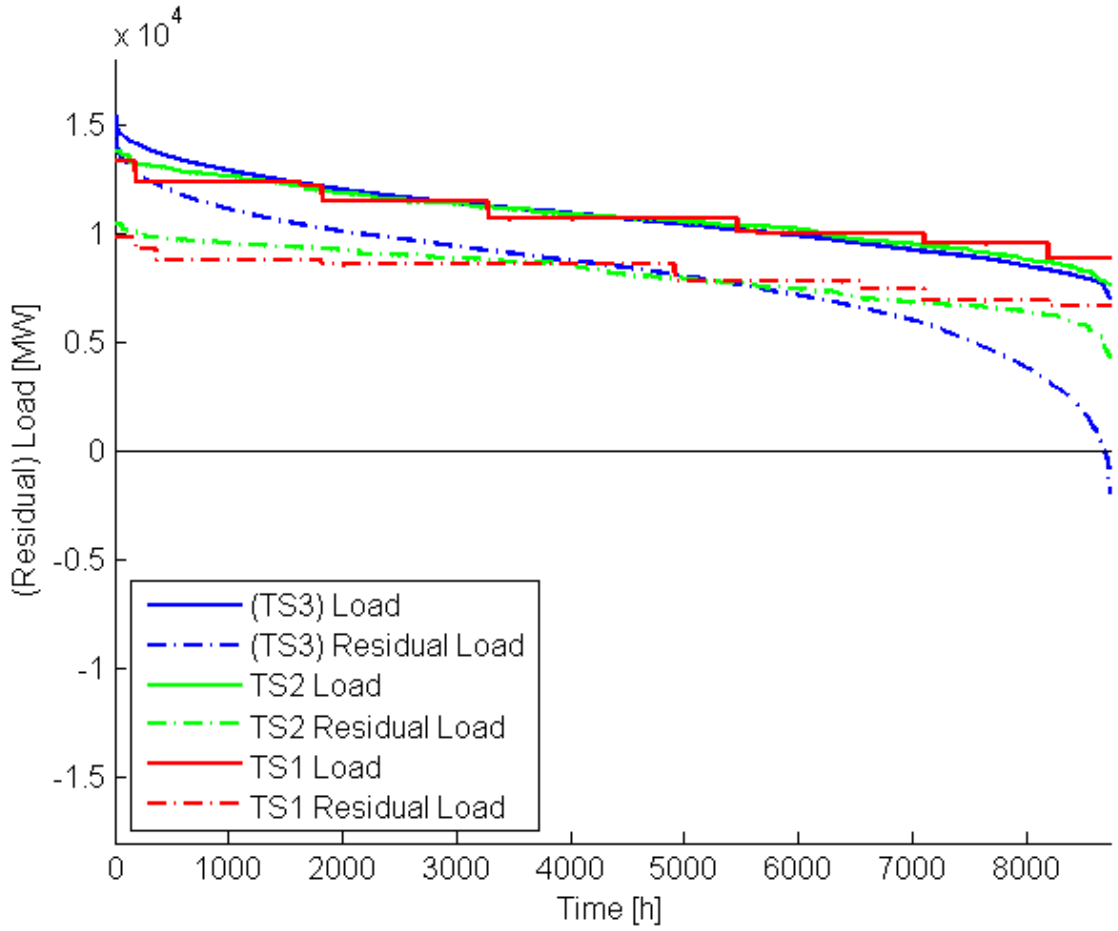
Residual Load Duration Curve (RLDC)

- 2020: 4.0 GW Wind, 1.9 GW PV



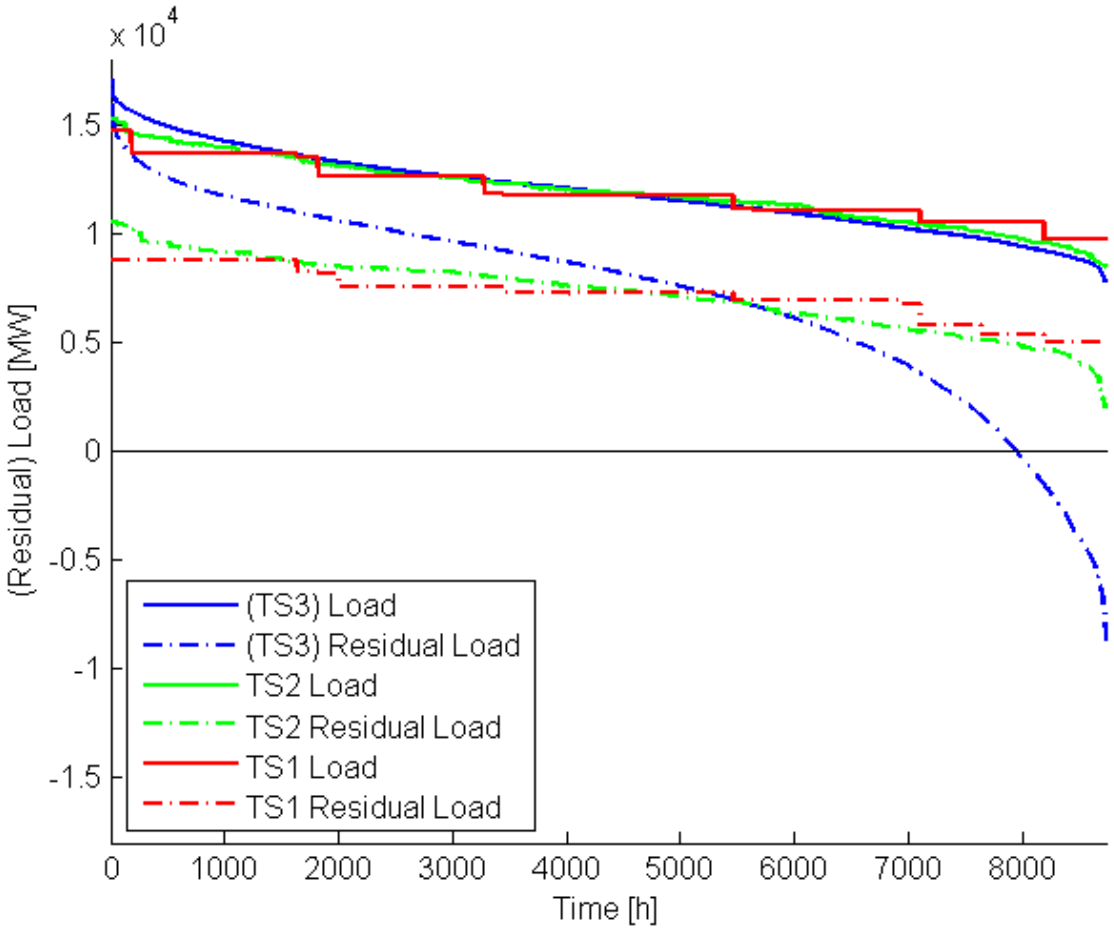
Residual Load Duration Curve (RLDC)

- 2030: 11.0 GW Wind, 0.9 GW PV



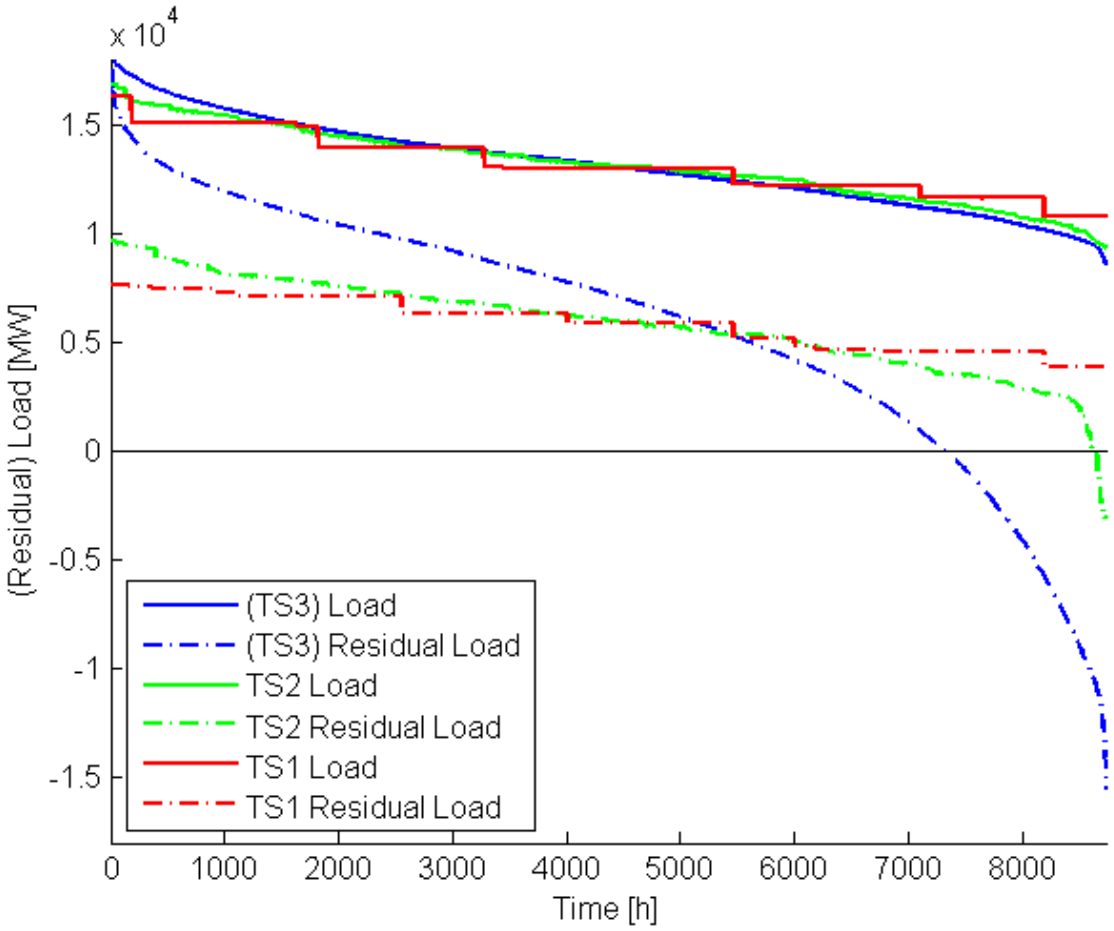
Residual Load Duration Curve (RLDC)

- 2040: 20.0 GW Wind, 0 GW PV

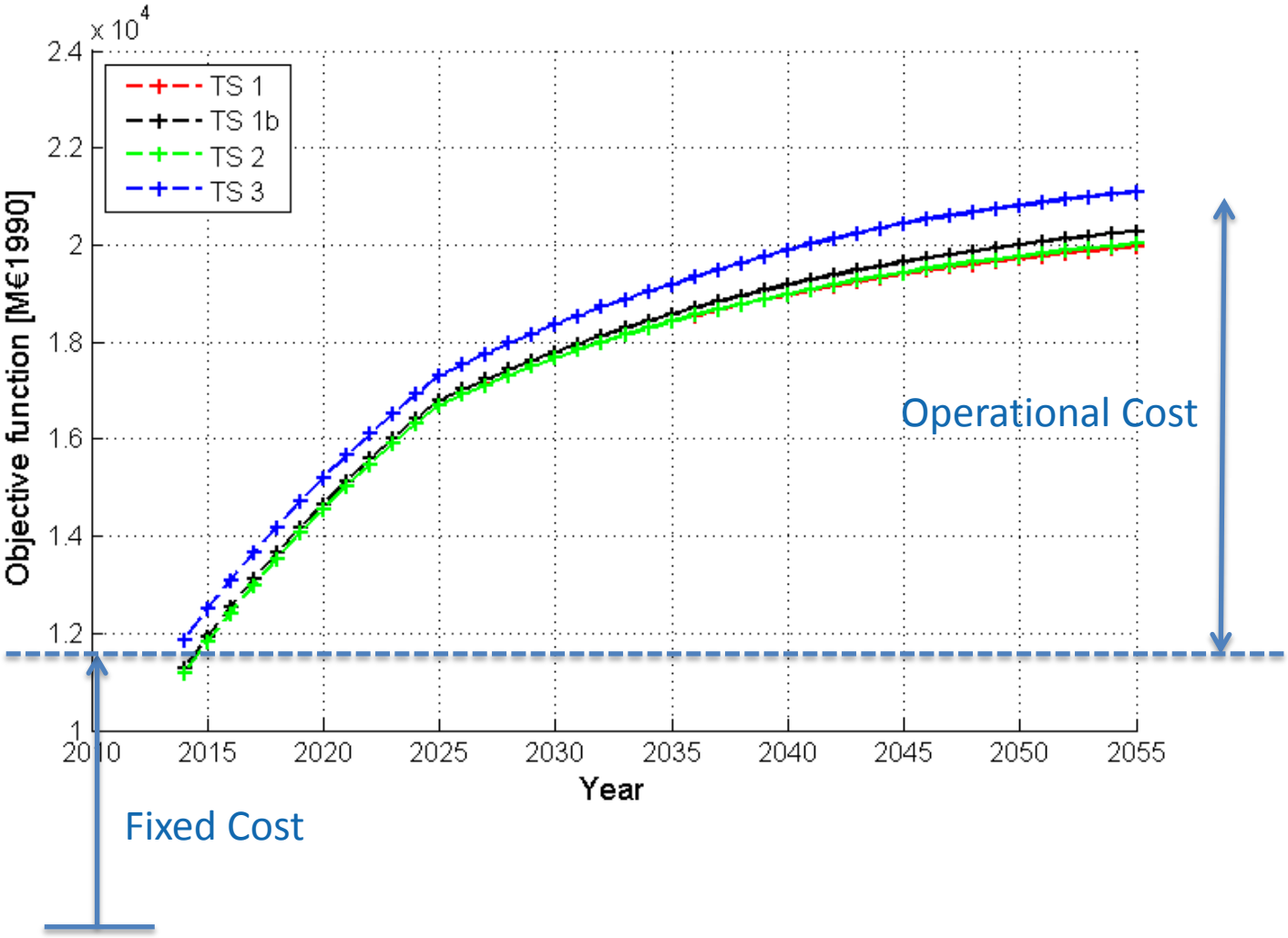


Residual Load Duration Curve (RLDC)

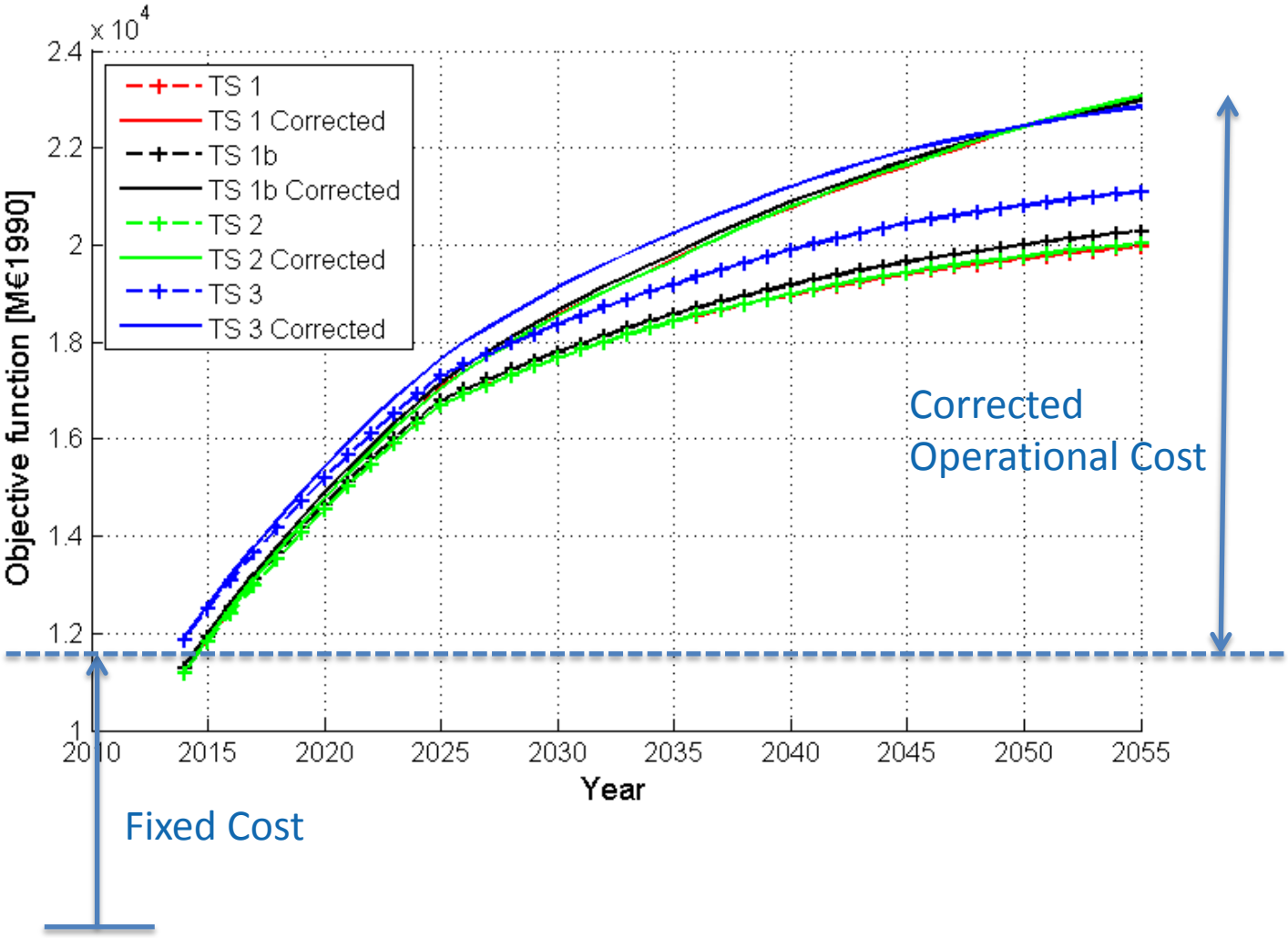
- 2050: 26.9 GW Wind, 8.8 GW PV



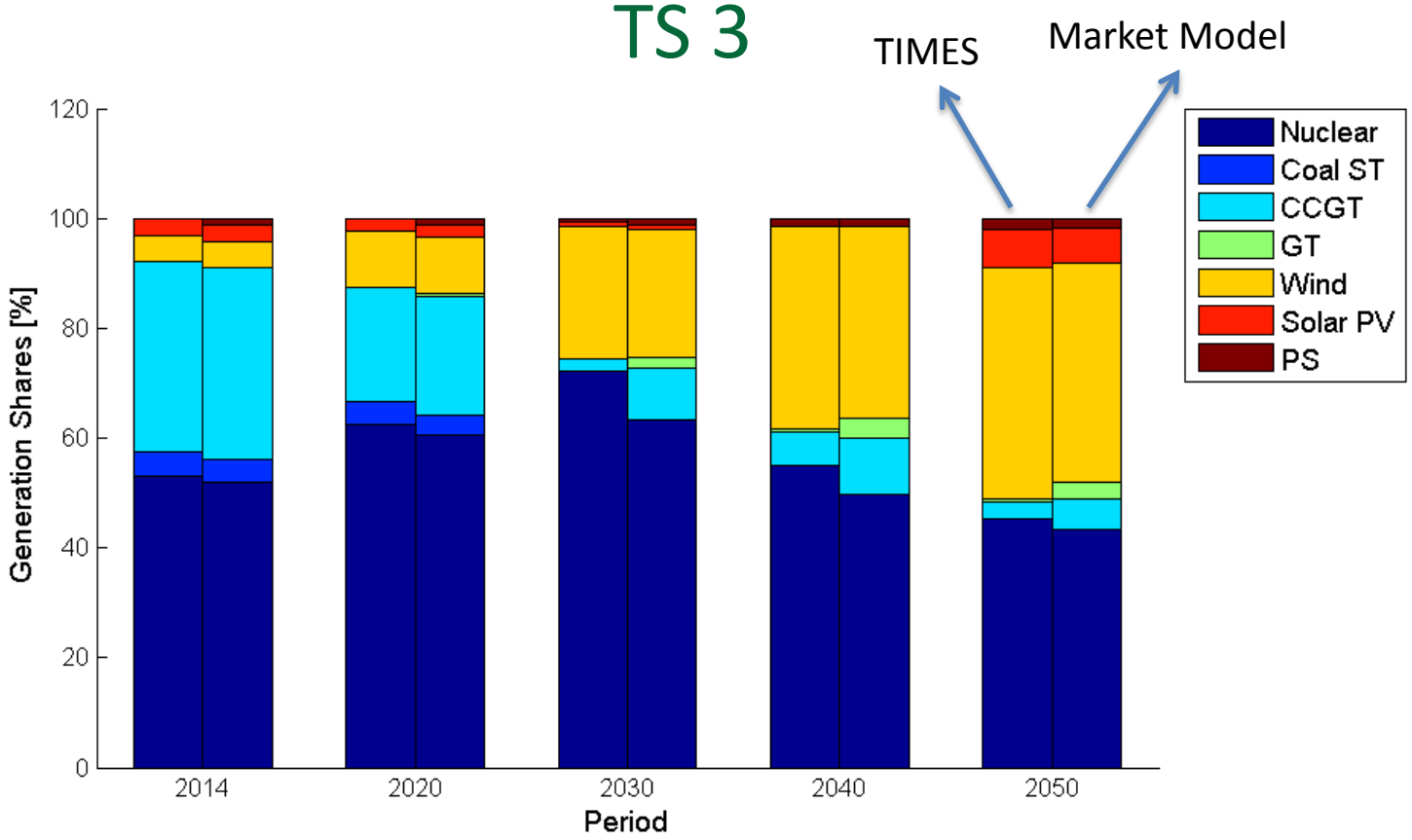
System Cost


x 10^4
2.4
2.2
2
1.8
1.6
1.4
1.2
1
Objective function [M€1990]
TS 1
TS 1b
TS 2
TS 3
2010
2015
2020
2025
2030
2035
2040
2045
2050
2055
Year
Operational Cost
Fixed Cost

System Cost - Corrected



Re-evaluate Dispatch – TS 3



RES Target [%]:	/	12.5	25	37.5	50
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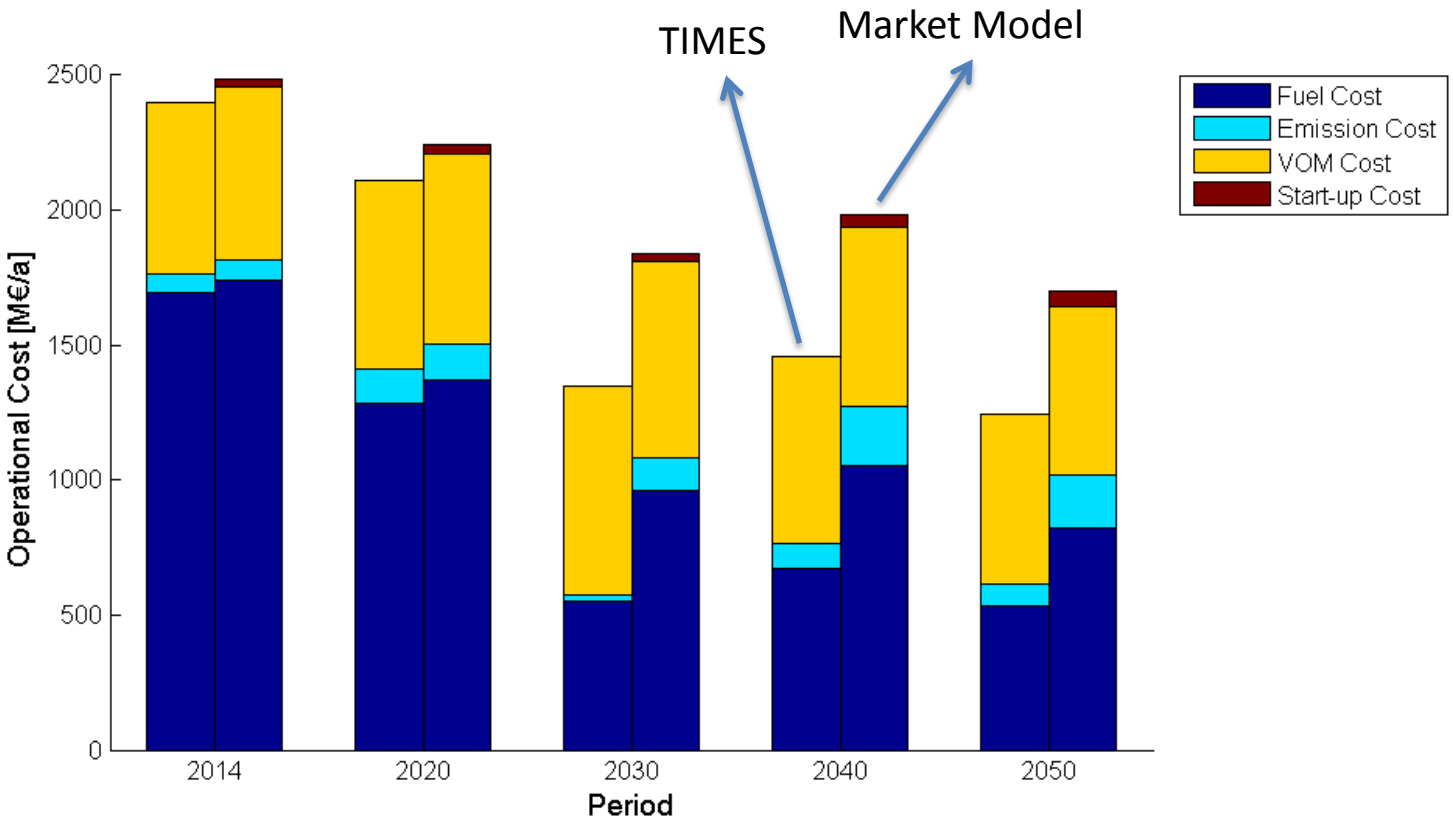
Impact Operational Constraints

TS 3



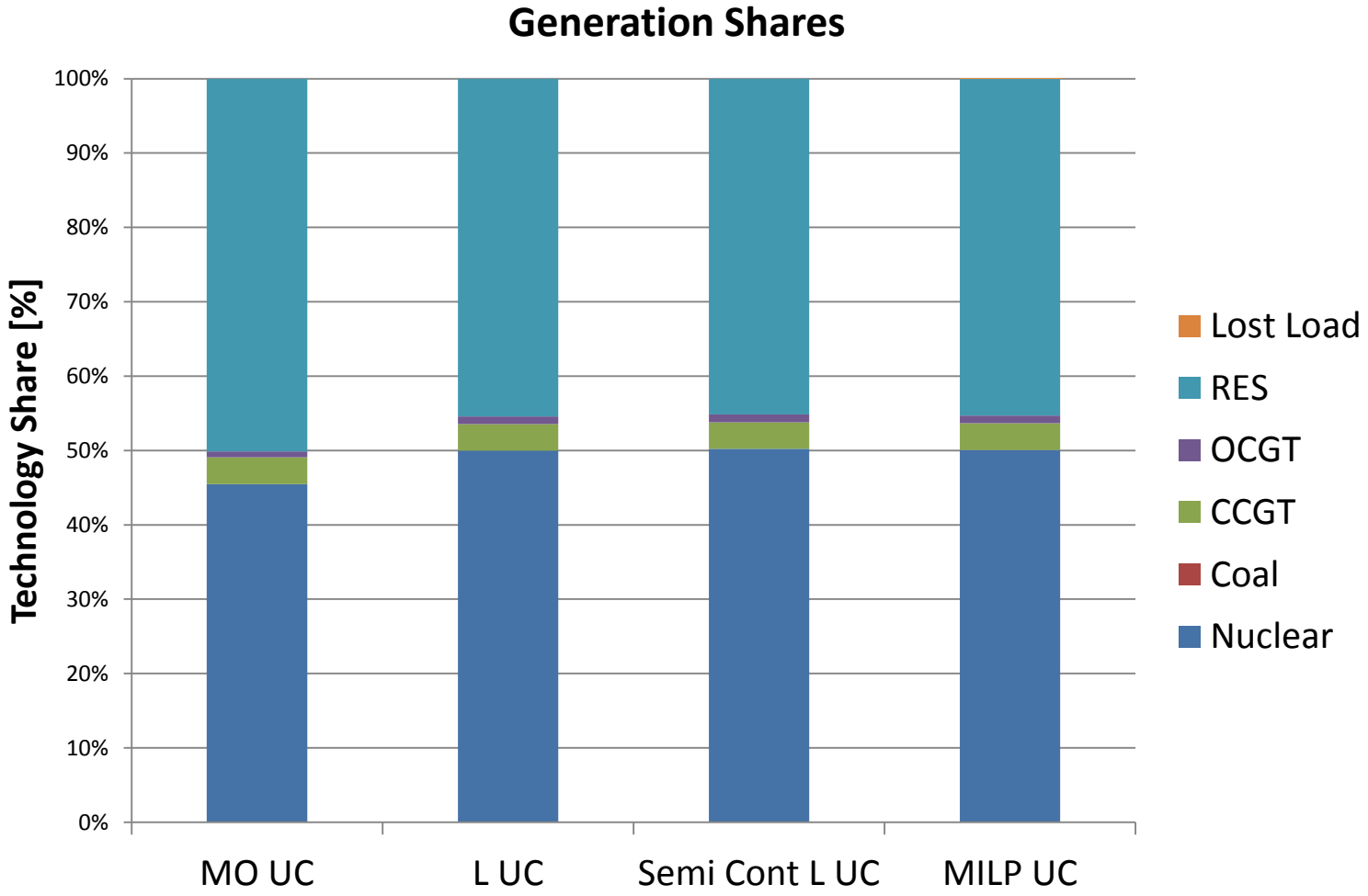
Conclusions

- 1) Use Time Slices:
  - classical division of TS based on seasonal, daily or intra-daily fluctuations can not be justified
- 2) Operational Constraints of power plants:
  - Can have a significant impact (dependent on power system)

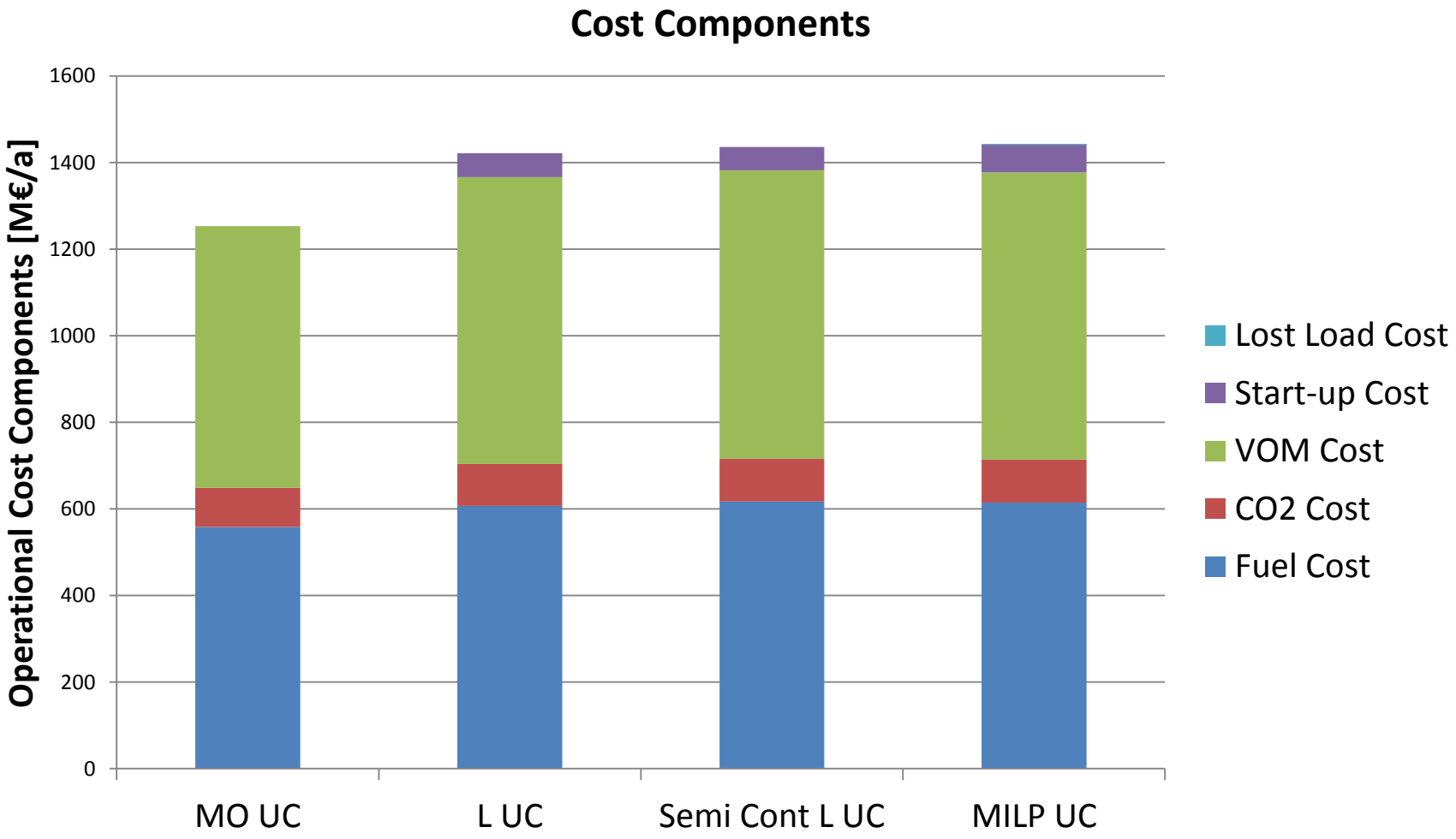
Solutions

- Direct integration of “technology-reflective” operational aspects:
  - Advantage: close to physical reality
  - Disadvantage: computationally demanding
    - A) Linearized non-integer operational constraints (‘L UC’)
    - B) Selection of representative days
- Direct integration of stylized operational aspects
  - E.g. Ramping rates reflecting all operational constraints
  - Advantage: lower computational effort
  - Disadvantage: less reflective of reality?
- Soft-linking with market model in an iterative approach

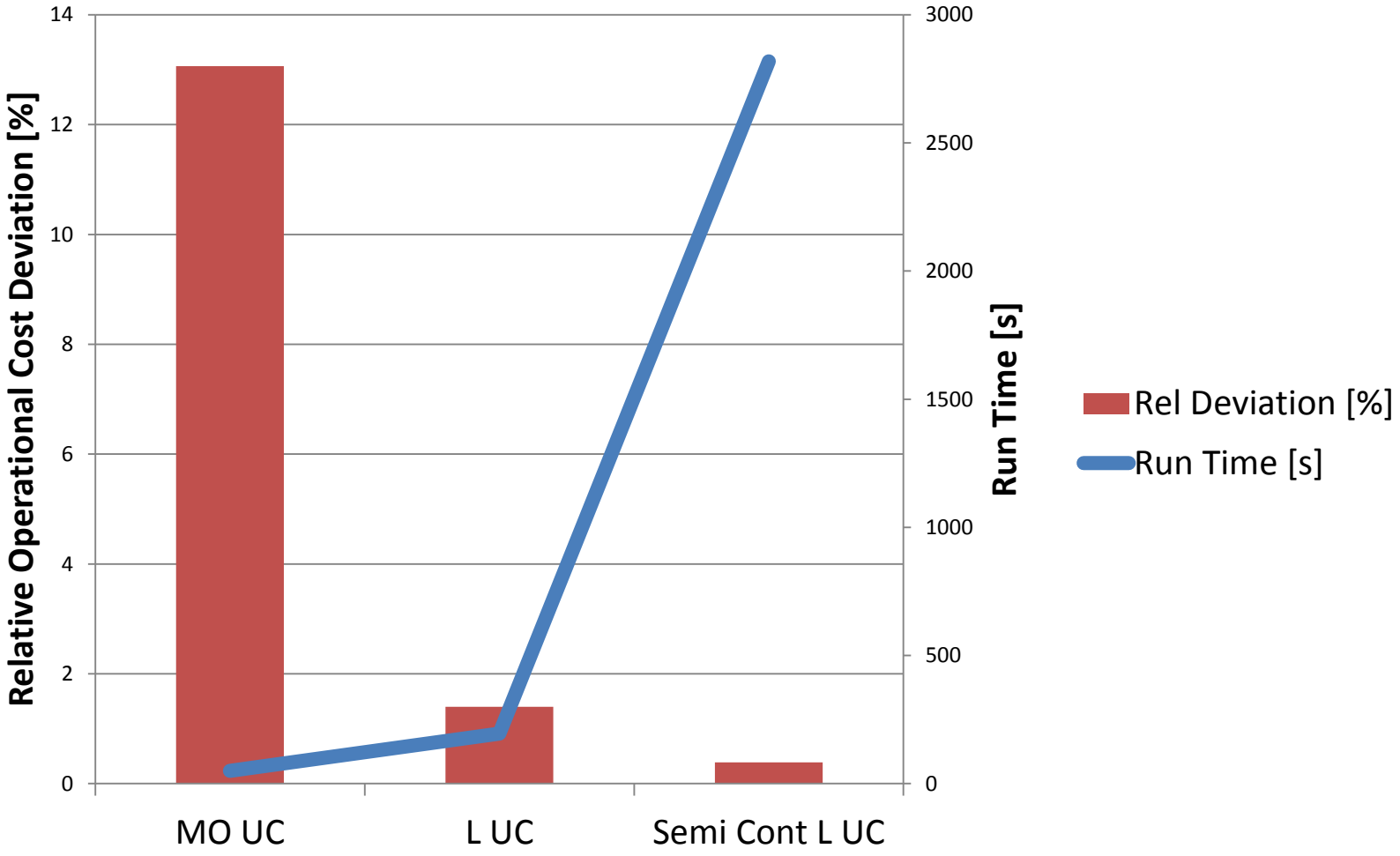
A) Linear UC


Generation Shares
Technology Share [%]
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
MO UC
L UC
Semi Cont L UC
MILP UC
Lost Load
RES
OCGT
CCGT
Coal
Nuclear

A) Linear UC


Cost Components
Operational Cost Components [M€/a]
1600
1400
1200
1000
800
600
400
200
0
MO UC
L UC
Semi Cont L UC
MILP UC
Lost Load Cost
Start-up Cost
VOM Cost
CO2 Cost
Fuel Cost

A) Linear UC


Relative Operational Cost Deviation [%]
Run Time [s]
0
2
4
6
8
10
12
14
0
500
1000
1500
2000
2500
3000
MO UC
L UC
Semi Cont L UC
Rel Deviation [%]
Run Time [s]

B) Selection of optimal days

- Multi-criteria optimization with some heuristics
- Ongoing research

Q&A

Questions?

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Model Results - Generation

- Generation